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DEFORMATION AND STABILITY ANALYSIS OF DOUBLE-WALL VERTICAL BREAKWATERS FOR EARTHQUAKE RETURN PERIODS

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ABSTRACT
Double-wall vertical breakwaters have been widely used during the past centuries, the using of double-wall sections which consist of combined sections have increased because of the progressive elaboration that has been happened in the civil and coastal engineering industry in offshore fields. This paper is discussing the deformation and the stability analysis for the double-wall vertical breakwaters for several return periods of earthquake and several breakwaters geometries. One of the advantages of studying stability and serviceability of the double-wall vertical breakwaters for different earthquake return periods, is to ensure the safety and the clearance spaces for using the suitable area of the double-wall vertical breakwaters as wharfs and as a path for the pipelines in the LPG harbours.

KEYWORD: Vertical breakwaters, Stability Analysis, Double-wall breakwaters.

INTRODUCTION
The stability analysis for the double-wall vertical breakwaters depends on several factors. The paper discusses the effect breakwaters geometries for several return periods of earthquake and several breakwaters geometries. The factors which have been used for the analysis are the double-wall vertical breakwaters width for earthquake return periods of 475 and 2475-year return periods.

ENVIRONMENTAL AND DESIGNING CONSIDERATIONS
The soil characteristics considered for the study is shown in the below table.

Table 1. Soil Characteristics.

Name	**G total**	**G dry**	**Frict**	**C'**	**kA$_p$**	**kP$_p$**	**EL**
	(kN/m3)	**(kN/m3)**	**(deg)**	**(kPa)**	**NL**	**NL**	**mCD**
Fill	20.5	17.27	35	0	0.27	3.69	+5.00
Den. Sand	20.5	17.27	40	0	0.22	4.6	-5.00

Where
G total is the total soil specific weight
G dry is the dry weight of the soil
Frict is the soil friction angle
C' is the effective cohesion
KA$_p$ is the peak active thrust coefficient
KP$_p$ is the peak passive thrust coefficient
EL is the top elevation of the soil
The geometries considered for the study is shown in the below figure.

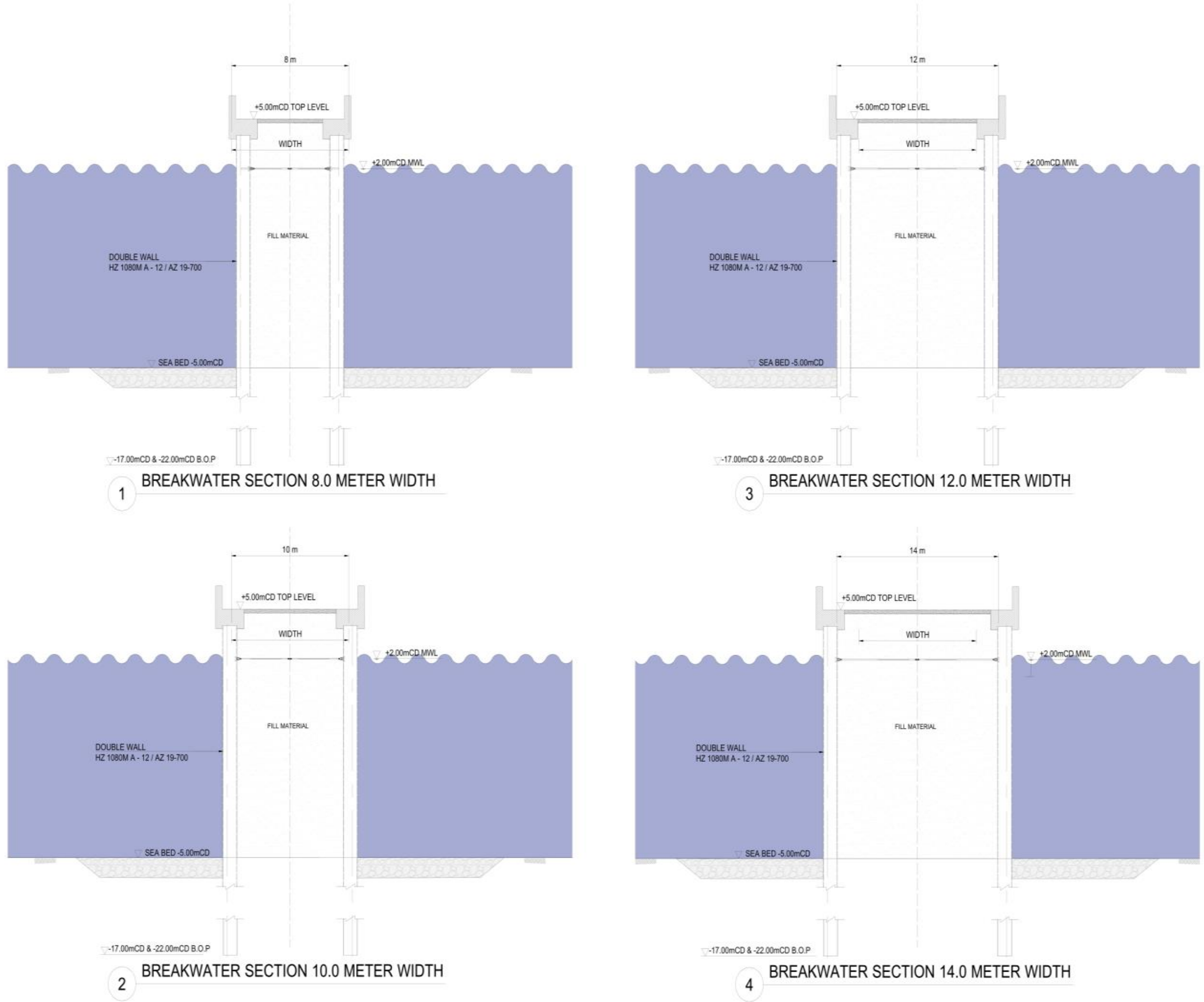
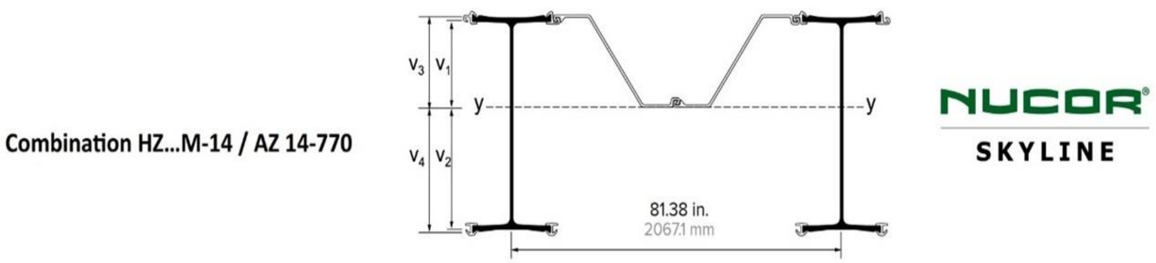


Figure 1: Breakwaters Geometries

The properties of the double-wall vertical breakwater section considered for the study is shown in the below figure.



SECTION	PROPERTIES PER FOOT OF WALL				MASS OF COMBINATION WITH INTERMEDIARY SECTION				
					*** AZ 14-770			Coating Area	
	Sectional Area in²/ft cm²/m	Moment of Inertia in⁴/ft cm⁴/m	*Elastic Section Modulus in³/ft cm³/m	**Elastic Section Modulus in³/ft cm³/m	ℓAZ = 60% ℓHZ lb/ft² kg/m²	ℓAZ = 80% ℓHZ lb/ft² kg/m²	ℓAZ = ℓHZ lb/ft² kg/m²	Waterside ft²/ft m²/m	Landside ft²/ft m²/m
HZ 1180M D	19.68 426.4	5035.9 687693	**233.5 12553.7**	226.4 12172.0	57.68 281.62	62.32 304.27	66.96 326.93	8.16 2.487	18.29 5.575

Figure 2: Properties of the Double-Wall Vertical Breakwater

The related peak ground accelerations considered in the numerical modelling for the analysis of the earthquake return periods of 475 and 2475-year return periods for the Middle East are shown in the following table [1] [2].

Table 2. Model Peak Ground Accelerations.

Name	**PGA**	**W**	**B.O.P**
	g	**m**	**mCD**
Model 1	0.10	8.0	-17.00
Model 2	0.10	10.0	-17.00
Model 3	0.10	12.0	-17.00
Model 4	0.10	14.0	-17.00
Model 5	0.33	8.0	-17.00
Model 6	0.33	10.0	-17.00
Model 7	0.33	12.0	-17.00
Model 8	0.33	14.0	-17.00
Model 9	0.33	8.0	-22.00
Model 10	0.33	10.0	-22.00
Model 11	0.33	12.0	-22.00
Model 12	0.33	14.0	-22.00

Where
PGA is the peak ground acceleration
W is the double-wall vertical breakwater width
B.O.P is the bottom elevation of the breakwater

MODELLING AND RESULTS

The numerical modelling considered for the study was built using limit equilibrium method for the soil modelling which is an analysis method where the limit state conditions are assumed. 12 models have been analysed to study the effect of the double-wall vertical breakwaters width for earthquake return periods of 475 and 2475-year return periods.

The earthquake return periods of 475 years, and 2,475 years are corresponding to 10% and 2% probabilities of exceedance in 50 years [3]. The bearing capacity and soil layers should be studied and checked for each site [4]. The wave characteristics can be expected using the linear wave theory [5]. However, the effect of the wave forces have been neglected for the study of the service and earthquake combinations. The below figures represent the analysis results of the 12 models for base service and Earthquake cases [6].

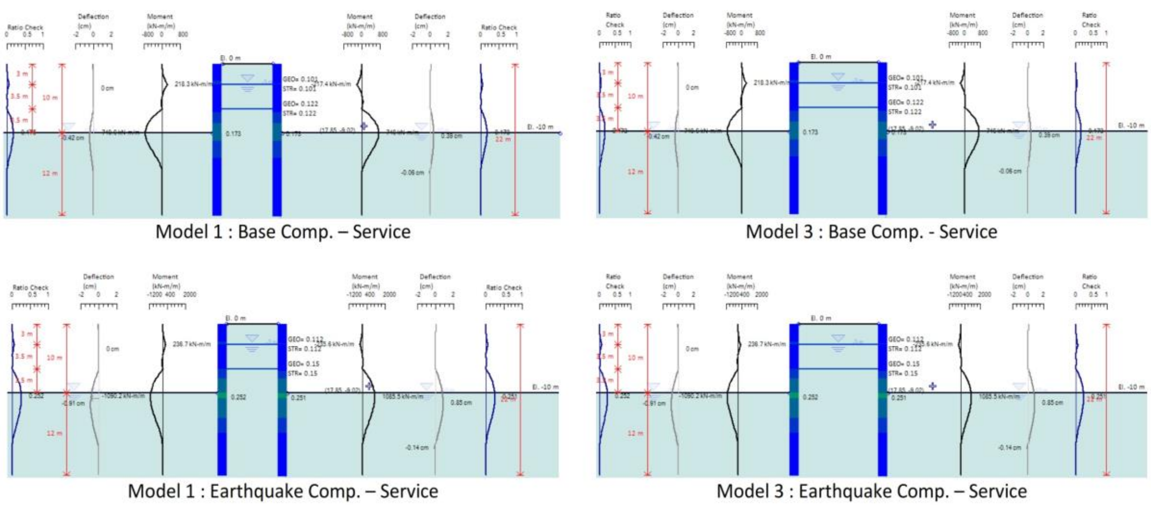
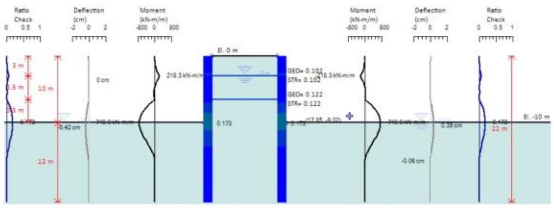
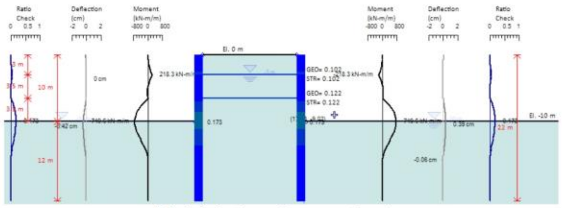


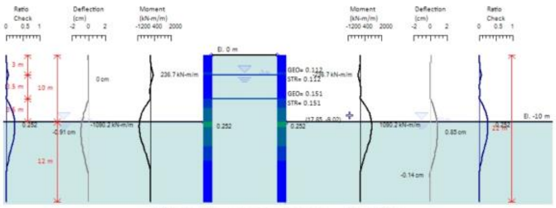
Figure 3: Analysis Results (1/4)



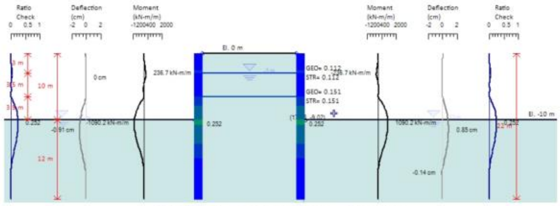
Model 2 : Base Comp. – Service



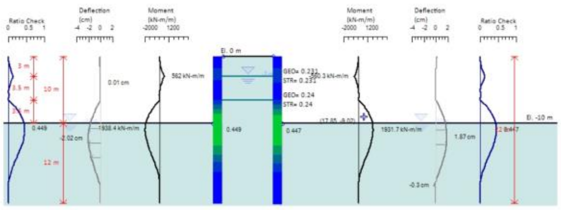
Model 4 : Base Comp. – Service



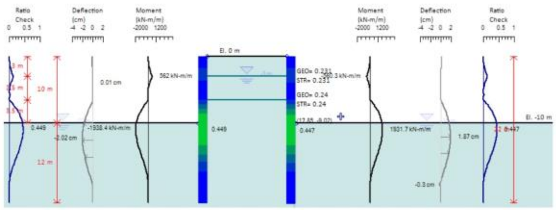
Model 2 : Base Comp. - Service



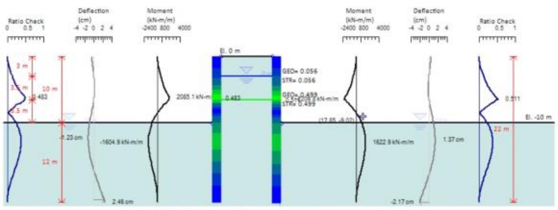
Model 4 : Base Comp. – Service



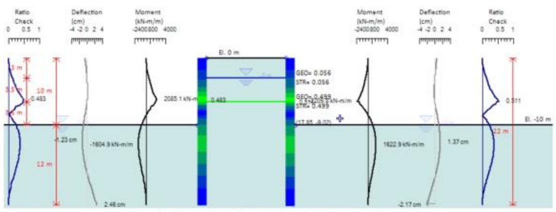
Model 5 : Base Comp. – Service



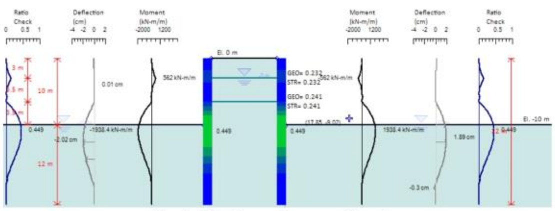
Model 7 : Base Comp. – Service



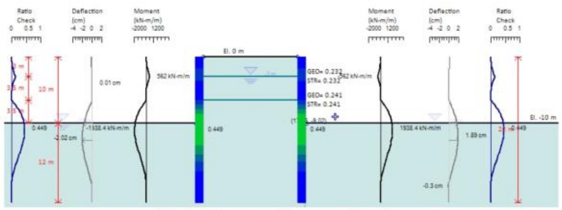
Model 5 : Earthquake Comp. – Service



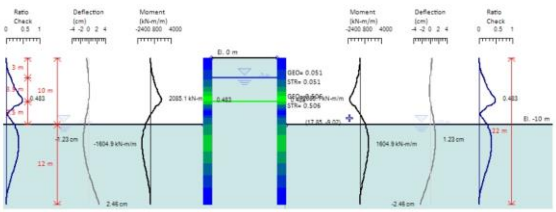
Model 7 : Earthquake Comp. – Service



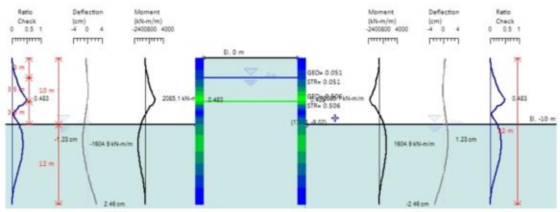
Model 6 : Base Comp. – Service



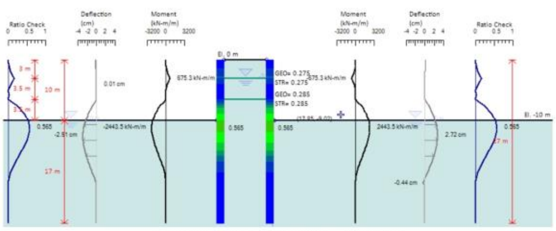
Model 8 : Base Comp. – Service



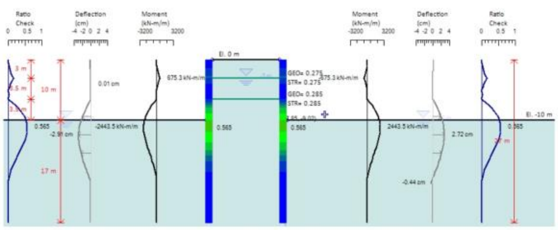
Model 6 : Base Comp. – Service



Model 8 : Base Comp. – Service

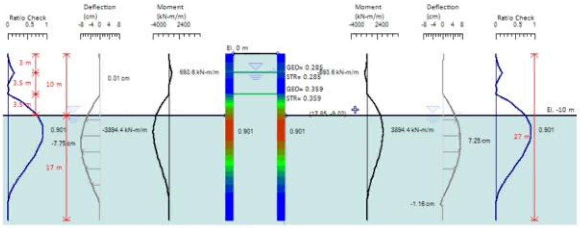


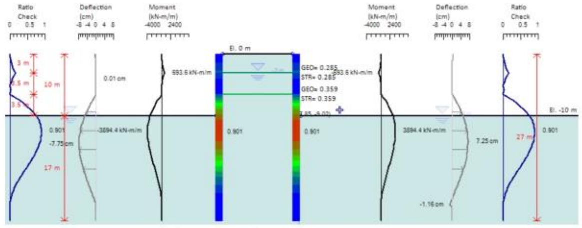
Model 9 : Base Comp. – Service

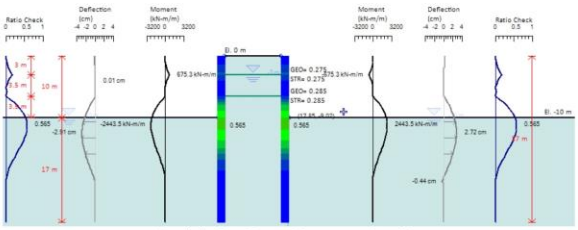


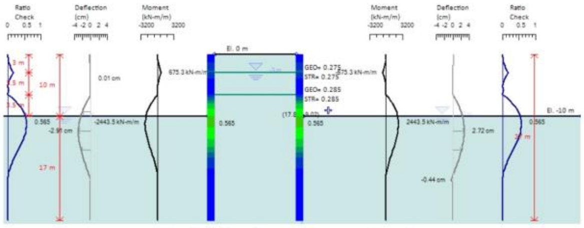
Model 11 : Base Comp. – Service

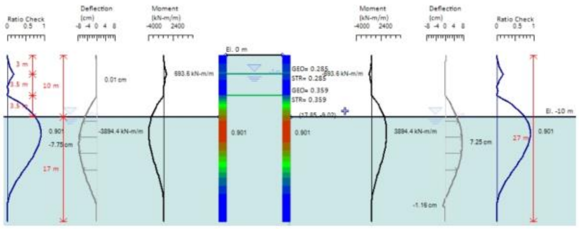
Figure 4: Analysis Results (2/4)


Model 9 : Earthquake Comp. – Service


Model 11 : Earthquake Comp. – Service


Model 10 : Base Comp. – Service


Model 12 : Base Comp. – Service


Model 10 : Base Comp. - Service

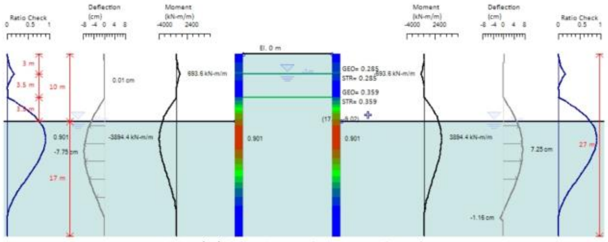

Model 12 : Base Comp. – Service

Figure 5: Analysis Results (3/4)

	Wall Dis.(cm)	Wall Moment (kN-m/m)	Wall Shear (kN/m)	STR Combined Wall Ratio	STR Moment Wall Ratio	STR Shear Wall Ratio	Max Support R. (kN)	Critical Support Check	STR Support Ratio
Model 1 : Base Comp.	0.600	777.0	677.0	0.180	0.180	0.194	1489.0	0.122	0.122
Model 1 : EQ Comp.	1.020	1094.0	753.0	0.253	0.253	0.215	1829.0	0.150	0.150
Model 2 : Base Comp.	0.600	777.0	677.0	0.180	0.180	0.194	1495.0	0.122	0.122
Model 2 : EQ Comp.	1.020	1094.0	749.0	0.253	0.253	0.214	1838.0	0.151	0.151
Model 3 : Base Comp.	0.600	777.0	677.0	0.180	0.180	0.194	1489.0	0.122	0.122
Model 3 : EQ Comp.	1.020	1094.0	753.0	0.253	0.253	0.215	1829.0	0.150	0.150
Model 4 : Base Comp.	0.600	777.0	677.0	0.180	0.180	0.194	1495.0	0.122	0.122
Model 4 : EQ Comp.	1.020	1094.0	749.0	0.253	0.253	0.214	1838.0	0.151	0.151
Model 5 : Base Comp.	2.020	1938.0	855.0	0.449	0.449	0.245	2937.0	0.240	0.240
Model 5 : EQ Comp.	2.460	2210.0	1245.0	0.511	0.511	0.356	6091.0	0.499	0.499
Model 6 : Base Comp.	2.020	1938.0	855.0	0.449	0.449	0.245	2948.0	0.241	0.241
Model 6 : EQ Comp.	2.460	2085.0	1245.0	0.483	0.483	0.356	6181.0	0.506	0.506
Model 7 : Base Comp.	2.020	1938.0	855.0	0.449	0.449	0.245	2937.0	0.240	0.240
Model 7 : EQ Comp.	2.460	2210.0	1245.0	0.511	0.511	0.356	6091.0	0.499	0.499
Model 8 : Base Comp.	2.020	1938.0	855.0	0.449	0.449	0.245	2948.0	0.241	0.241
Model 8 : EQ Comp.	2.460	2085.0	1245.0	0.483	0.483	0.356	6181.0	0.506	0.506
Model 9 : Base Comp.	2.910	2444.0	1023.0	0.565	0.565	0.293	3486.0	0.285	0.285
Model 9 : EQ Comp.	7.750	3894.0	1313.0	0.901	0.901	0.376	4387.0	0.359	0.359
Model 10 : Base Comp.	2.910	2444.0	1023.0	0.565	0.565	0.293	3486.0	0.285	0.285
Model 10 : EQ Comp.	7.750	3894.0	1313.0	0.901	0.901	0.376	4387.0	0.359	0.359
Model 11 : Base Comp.	2.910	2444.0	1023.0	0.565	0.565	0.293	3486.0	0.285	0.285
Model 11 : EQ Comp.	7.750	3894.0	1313.0	0.901	0.901	0.376	4387.0	0.359	0.359
Model 12 : Base Comp.	2.910	2444.0	1023.0	0.565	0.565	0.293	3486.0	0.285	0.285
Model 12 : EQ Comp.	7.750	3894.0	1313.0	0.901	0.901	0.376	4387.0	0.359	0.359

Figure 6: Analysis Results (4/4)

CONCLUSION

The sensitivity analysis considered of the study for the 12 models has shown that higher PGA is corresponding to the higher settlement and deformation of the double-wall vertical breakwaters and corresponding less to the width of the breakwaters. The below figures represent the sensitivity analysis results of the 12 models for base service and Earthquake cases.

Figure 7: Sensitivity Analysis Results

The Study recommends to use the sensitivity analysis for the safety the double-wall vertical breakwaters with the economical construction cost of the breakwater width. The study recommends to study the minimum embedded depth of the double-wall vertical breakwater for earthquake return period of 2,475 years for the liquefiable soil layers

REFERENCES

1) Lotfollahi-Yaghin, M.A., Gholipour Salimi, M. and Ahmadi (2013). Probabilistic Assessment of Pseudo-Static Design of Gravity-Type Quay Walls. Civil Engineering Infrastructures Journal, 46(2): 209 – 219, ISSN: 2322 – 2093.
2) Jamal A. Abdallah and Azm s. Al-homoud (2004). Seismic hazard assessment of United Arab Emirates and its surroundings. Journal of Earthquake Engineering, Vol. 8, No. 6, 817-837.
3) BS 6349-1-2:2016. Maritime works. General. Code of practice for assessment of actions.
4) M. Abouelnasr and M. Tarek, (2020). Case Study for Hollow Tubular Offshore Pile, Volume 7, International Journal for Research in Applied Science and Engineering Technology (IJRASET), Page No: 111-116, ISSN: 2321-9653
5) M. Abouelnasr and M. Tarek, (2020). Computational Tool for the Characteristics of Linear Water Waves using C# Language, Volume 9, Issue 11, International Journal of Engineering Science and Computing (IJESC), Page No: 24176 -24178, ISSN: 2321-3361
6) B. Simpson. (2007). Approaches to ULS design – The merits of Design Approach 1 in Eurocode 7, ISGSR2007 First International Symposium on Geotechnical Safety & Risk.